Enhancing data preparation for hydrological modeling: a Python-based approach for coupling SWAT+ and MODFLOW

Maciej Nikiel[1], Adam Szymkiewicz[2], Przemysław Wachniew[1], and Anna J. Żurek[1]

[1]AGH University of Krakow, Kraków, Poland [2]Gdańsk University of Technology, Gdańsk, Polannd

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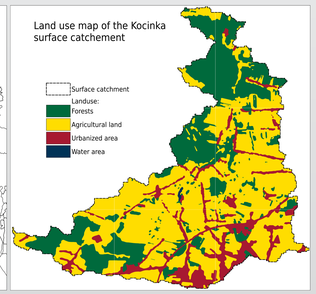
Outstanding Student & PhD candidate Presentation contest

INTRODUCTION

The Kocinka River catchment (250 km²) in southwestern Poland represents a typical agricultural landscape with 66% agricultural land use. The river extends 40 km with an average discharge of 1 m³/s and annual precipitation of 600-700 mm. The catchment overlies an important aquifer whose management depends on accurate groundwater forecasting. Our research addresses the challenge of modeling water fluxes from surface through unsaturated and saturated zones to the river network, accounting for diverse land uses and the significant groundwater contribution to streamflow. This complexity necessitates the development of efficient data preparation and model coupling methodologies between SWAT+ and MODFLOW.



OBJECTIVES

Our research aims to address the challenges of hydrological model data preparation through automation and standardization. The primary goal is to develop a comprehensive Python-based framework that streamlines the integration of diverse data sources required for coupled SWAT+ and MODFLOW models. This framework focuses on:

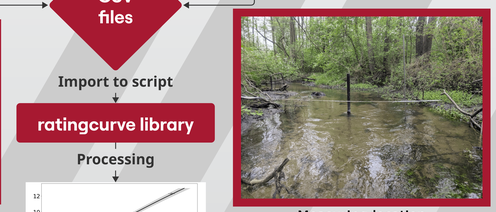
- minimizing manual data handling to reduce potential errors;
- enabling efficient calibration through rapid parameter modifications;
- providing tools for automated water balance analysis;

By creating reusable scripts and workflows, we seek to establish a methodology that not only serves the current Kocinka River catchment study but can be readily adapted for similar hydrological investigations in other regions. Ultimately, this work contributes to enhancing reproducibility and transparency in complex modeling processes, particularly those involving groundwater-surface water interaction.

Rating Curves

Our rating curve development integrates continuous Odyssey depth logger measurements with HydroProfler discharge data collected across various flow conditions. Using Python scripts and the ratingcurve library, we process field data from CSV files to establish reliable stage-discharge relationships. These rating curves provide critical validation data for SWAT+ model calibration, ensuring accurate representation of hydrological response of Kocinka River.

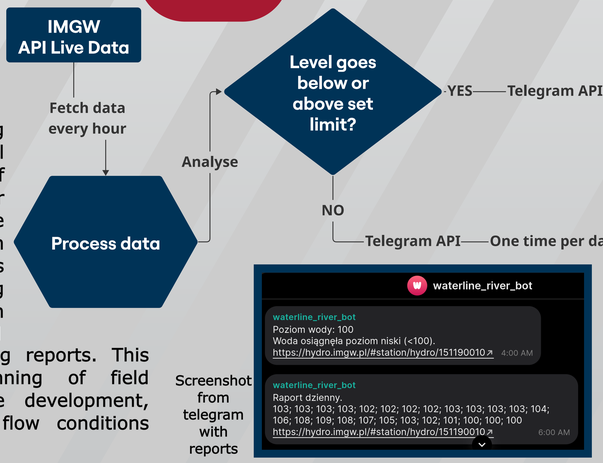
Measuring location



Measuring location

River Level Notifications

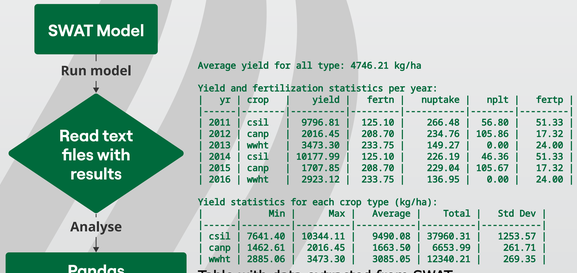
Our automated river monitoring system collects hourly water level data from the Polish Institute of Meteorology and Water Management (IMGW) API for the Kocinka River. The Python workflow processes measurements against set thresholds, sending real-time Telegram alerts when levels fall below or exceed critical values, along with daily morning reports. This system enables efficient planning of field measurements for rating curve development, ensuring we capture essential flow conditions without unnecessary site visits.



Screenshot from telegram with reports

Results Analysis

Our Python-based workflow automates SWAT model execution and results analysis. The process uses Subprocess to run the SWAT model, then employs Pandas to extract and analyze data from output text files. The workflow focuses on water balance components and crop yield analysis, with Tabulate generating formatted result tables. This approach eliminates manual errors and enables efficient model calibration.



Average yield for all type: 4746.21 kg/ha

Yield and fertilization statistics per year:

yr	crop	yield	fertn	nuptake	nplt	fertp
2011	csil	9796.81	125.10	266.48	56.80	51.33
2012	canp	2016.45	208.70	234.76	105.86	17.32
2013	wwht	3473.30	233.75	149.27	0.00	24.00
2014	csil	10177.99	125.10	226.19	46.36	51.33
2015	canp	1707.85	208.70	229.04	105.67	17.32
2016	wwht	2923.12	233.75	136.95	0.00	24.00

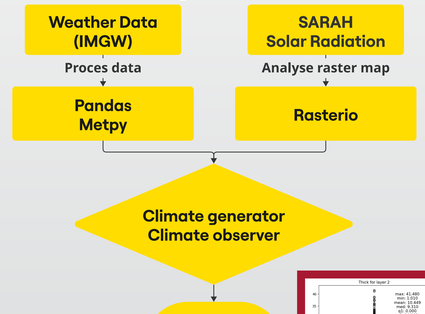
Yield statistics for each crop type (kg/ha):

	Min	Max	Average	Total	Std Dev
csil	7641.40	10344.11	9490.08	37960.31	1253.57
canp	1462.61	2016.45	1663.50	6653.99	261.71
wwht	2885.06	3473.30	3085.05	12340.21	269.35

Table with data extracted from SWAT

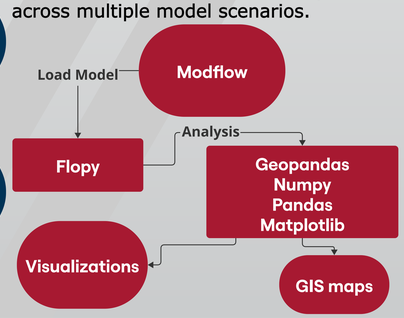
Climate Data

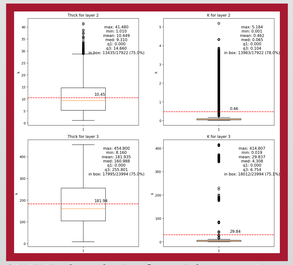
Our Python-based workflow processes meteorological inputs for SWAT+ modeling using Pandas and Metpy libraries. We integrate IMGW weather data with SARAH solar radiation data, employing Rasterio for spatial analysis and custom modules to generate SWAT-compatible outputs, significantly reducing manual data handling time.



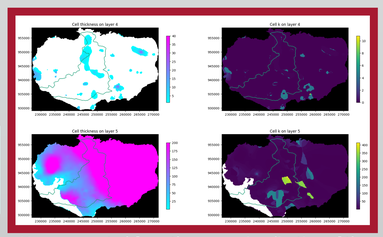
Model Visualisation

Our Python workflow uses Flopy to extract MODFLOW data, with NumPy, Pandas, Geopandas, and Matplotlib for efficient visualization. This approach generates customized groundwater visualizations faster than GUI methods, with seamless GIS export capabilities and consistent presentation across multiple model scenarios.





Statistical analysis of crucial parameters.



Maps generated from the mass visualization of the MODFLOW model.

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